BLT Acquisition Features

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Summary

This paper describes the acquisition setup and capabilities for the Beam Line Tuner system for the Main Injector.

1. Introduction

The Beam Line Tuner takes beam position data on a turn by turn basis to measure the betatron oscillation at injection. There are two possible hardware configurations. One uses the V177 timing card and VX4240 digitizer, the second uses the VXI-UCD timing card and the V440 digitizer. The first configuration has a timing resolution of 7 buckets and can digitize up to 10 Mhz. This configuration is suitable for use with the Main Ring RF modules. The second configuration has a timing resolution of one bucket and can digitize each bucket (with certain limitations). This second configuration can use the output of the superdamper integrator. In both cases more than one bunch can be sampled at the same time. This allows measuring the kick on buches already injected or looking at batch injections. Currently, the first configuration is used for the Tevatron while the second configuration is used for the Main Injector. This paper focusses on the Main Injector configuration

2. Main Injector Configuration

The V440 digitizer supports digitizing a specific number of samples at the sample clock rate (53MHz) per trigger. In the measurement specification this number is represented in the hits/trigger field. The pattern determines how many triggers per turn are given. The digitizer can take up to 64 kilosamples of data.

The maximum number of turns that data can be taken is as follows:

$$\text{turns} = 65536/(\text{Hits/trigger} \cdot \text{triggers/pattern})$$

The beam line tuner can perform the following measurements:

1. Bucket Injection tuning: The pattern is defined by a pulse for each filled bucket (bunch). The minimum number of turns should be 1024 to allow for processing. The Hits/trigger is one, thus allowing to measure up to 64 bunches per injection. Note that the digitizer uses edge triggering and that the VXI-UCD card can only give an edge each other bucket. Also the digitizer can not retrigger within 8 clock cycles (53Mhz) after the last sample has been taken (including possible trigger delays, which are set during calibration, most likely to be zero)

2. Present bunch diagnostics. The pattern is defined by a pulse for each bunch already in the ring. One can look to see if any of the residing bunches was kicked while a new bunch was injected. The Hits/trigger is one, thus allowing to measure up to 64 bunches per injection.

3. Kicker diagnostics: A batch of filled buckets is injected. The Hits/trigger can be set to cover the whole batch. The pattern should have only one trigger. Thus allowing data for 65536/(Hits/trigger) turns. This data could be presented in a waterfall plot to show kicker performance. It can show if the kicker kicked all bunches equally and how the position of the bunches varies over each turn.

4. Ring diagnostics. The digitizer will take data for every bucket minus the retrigger time of 8 buckets. For Main injector this is 588 (-8 = 580) resulting in that 111 turns can be measured. Note that unfilled buckets are also sampled and so that much of the sampled data is wasted.

Additional measurements can be done using options on the analysis:

1. First Bunch: If there are more than 1 hits/trigger (thus sampling a batch), only the first bunch (of the batch) is being analyzed.

2. All: If there are more than one hits/trigger, all bunches in the batch are analyzed.

3 Average: If there are more than one hits/trigger, the position data of all bunches is averaged and then analyzed.

Another limitation in the amount of data available to the console is that Acnet does only support transfers of up to 4000 bytes or 1000 single float numbers. This would mean that 66 transfers for horizontal and 65 transfer for vertical position data are needed. Currently this problem is not yet resolved. For regular operation data for only 1024 turns is taken for analysis and only 256 samples are available to a console and only the first 36 bunches. Other data is not available over Acnet.

Summary of Acquisition Limitations

I. V440 needs 8 buckets between each trigger
II. V440 has 64 kilosample memory]
III. VXI-UCD can only give an edge every other bucket.
IV. Acnet data transfers up to 4000 bytes per message.

4 Timing Setup

Data-acquisition trigger

The actual trigger is determined by two events, the selected cycle reset and the trigger event that will trigger the data-acquisition. The cycle reset event can be x20, x21, x23, x29, x2A, x2B, x2D, x2E, and ANY of the above. If a particular event is selected the system will only trigger after first having received the particular cycle reset event and then the trigger event. If the option ANY is selected the first condition for the trigger will be always true. In both cases the data TAG will contain the cycle on which the data was taken.

As more than one batch can be injection, the user can also identify the batch to be sampled. This is done using the parameter CNT. If this is more than one then the data will be acquired on the nth occurrence of the trigger event. The maximum value is 12. If the value is 0 then the trigger event is not used and the data-acquisition is triggered right after the cycle reset event.

The delay is specified in µsecs but rounded to the nearest whole turn. So the stepsize is about 11 µsecs. This is done to always trigger on the same bunch.

Cycle	0xXX	0xXX	Any	Any
Trigger	0xYY	0xYY	0xYY	0xYY
Cnt	1-12	0	1-12	0
Delay	Z	Z	Z	Z
Method	1	2	3	4

Table X. Triggering methods.

The explanation of the trigger methods is as follows:

1 *Nth on Cycle*: Data is taken after a **Delay** of Z µsecs on the **Cnt**th occurrence of **Trigger** 0xYY after the reset **Cycle** event 0xXX.

2 *On Cycle*: Data is taken after a **Delay** of Z µsecs on after the reset **Cycle** event 0xXX.

3 *Nth on Any*: Data is taken after a **Delay** of Z µsecs on the **Cnt**th occurrence of **Trigger** 0xYY after any of the reset **Cycle** events.

4 *On Any*: Data is taken after a **Delay** of Z µsecs on after any reset **Cycle** event.

Synchronizing to a bunch

As more than one bunch per turn can be sampled, it is important that always the same bunch is the first to be sampled. This means that the TCLOCK event must be synchronized to the beam marker. This is done using the Output Mode Control Register. A TCLOCK event will set Channel 6 to low, while the beam marker will set Channel 6 to high. Even the beam marker will set the output to high every turn. This can only be seen when the TCLK event has reset the channel. Thus a upgoing edge is generated on the first marker after the TCLK event. To avoid synchronization problems within the digitizer, a trigger is only given to the digitizer when data needs to be taken and a separate arm event is not used.

Alternative Timing Setup

One way to evade the limitations of the V440 retrigger rate is to feed the signal of the PPG of the VXI-UCD to the digitizer's clock input itself and set the digitizer to always sample. If the VXI_UCD could be modified to give a pulse (edge) for each TRUE value in the PPG then all bunches could be sampled in any combination.

VXI-UCD Setup

The VXI-UCD is setup to implement all these different triggering methods. The page control is used to count the number of data triggers by switching to a different page on each repeated trigger until the last trigger which will reset the page to 0, set OUT2, and reset OUT6. With OUT6 reset, the next BSYNC AA marker can now set it to pulse the PWD which will, after a delay, trigger the PPG. The PPG now triggers the digitizer to take data. Table Y shows the setup of TCLOCK option memory, listing the bits set and to what output they are routed. Depending on the method active, different settings are made for the Cycle and Trigger.

Event	Option Memory / Output			
Trigger	D0-D3	D8	D12	
	PAGE	OUT2	OUT6	
Marker		D9	D13	
		OUT3	OUT6	
Cycle	D1[1]	D5	D10	D12[2]
	PAGE2	FIFO	OUT 4	OUT6
PPG	D0			
	OUT0			

TableY. Setup of VXI-UCD triggers. [1)] On Nth on Cycle and Nth on Any only. [2)] On On Cycle and On Any only.

Alternative Configuration Setup

The Beam Line Tuner can handle both Fast Integrator and RF Modules as preprocessors. If the configuration variable *Preprocessor* is set to Fast Integrator then the software assumes the connections as in table 1. Use table 2 for the RF Module configuration.

Table 1. Signals to digitizer using Fast Integrator.

Channel	Signal
1	Horizontal A-B
2	Horizontal A+B
3	Vertical A-B
4	Vertical A+B

Table 2. Signals to digitizer using RF Module.

Channel	Signal
1	Horizontal Pos
2	Vertical Pos
3	Not used
4	Not used

In Fast Integrator mode the A-B data is divided by A+B data to calculate the position. Note that when actually hooking up the Fast Integrator but setting the software in RF Module proprocessing mode. The resulting data represents the intensity not the position.

Output	Pulses
0	**PPG pattern**
1	-
2	**TCLK Event**
3	**BSYNC Marker**
4	-
5	-
6	**Synchronized TCLK**
7	-

Table 1. VXI-UCD Output assignments.

Notes: To set the hardware the global version of the pattern is used. The Acnet version is not being used even though it is defined.

2. Start of Fly or TCLOCK Timing

To trigger the fly, the software sets a VUCD card to look at the defined fly event. On receiving the TCLOCK the VUCD card asserts the IRQ 1 line and the front panel output 0 for monitoring purposes. The interrupt is implemented using scalars. To set the scalar 0 and Instrumentation Output 0, the value 0x10040 is written the address for the fly event. The scalar count registers are set for a single count, the interrupt ICR2 is enabled only for Channel 0 (related to event scalar 0), the interrupt level ICR1 is set to 1, and the backup channels ICR0 (720Hz) are disabled. The interrupt vector's value doesn't really matter but is set to 0x10.

To receive the IRQ1 interrupt in LabVIEW:

I. 1) InitVXIlibrary
II. 2) RouteVXIint: route the IRQ1 interrupt as a VME interrupt and handle as a 8 bit VME status vector
III. 3) SetVXIhandler: set the default interrupt handler for IRQ1
IV. 4) Option a) or b):
V. a) use PollVXIintHandlerTmo
  VI. a1) **EnableVXIint:** Enable for IRQ1 to allow PollVXIintHandlerTmo to receive the interrupt.
  VII. a2) **PollVXIintHandlerTmo**: set for IRQ1 to wait for interrupt
VIII. b) use VXIbusStatus and AcknowledgeVXIint
  IX. b1) **DisableVXIint**: to disable automatic handling of interrupt
  X. b2) **VXIbusStatus**: check for interrupt
  XI. b3) AcknowledgeVXIint: manually acknowledge interrupt

Note: if RouteVXIint and SetVXIhandler are not executed then the EnableVXIint and DisableVXIint seem to have no effect.

The AcknowledgeVXIint can still be used with option A if the DisableVXIint has been called. One could clear up the interrupts this way. This is necessary because the VUCD card will queue up to 1024 interrupts when the interrupt line is not being acknowledged. One could also clear the interrupt queue with a command to the VUCD card.

If you run CloseVXILibrary while interrupts are still enabled, they will be disabled. E.g. the VUCD will still interrupt but it will not be acknowledged. Opening the library will hang the machine at until the VME bus is reset (use button on MXI card):

```
Disassembling from 00304F2E
 d_SetVXIAccess
  +0000A 00304F2E BTST D0,(A6)| 0116
  +0000C 00304F30 BMI d_SetVXIAccess+00120;
```

Also the VXIinit and Resman need to be run to gain VME access again.

Note: CloseVXILibrary gives weird error codes when run when a routing is still active.

Note: If VXI library is not initialized, calls to e.g. VXIbusStatus will take up a lot of time (as each time the library is opened and closed)..

3. Calibration

Th Beamline Tuner must be calibrated to align timing and signal offsets.

3.1 Timing

Calibration of the timing allows the bucket number in the pattern definition menu to be aligned with the actual bucket of the beam as sampled by the digitizer. This calibration should only have to be done during installation or when the timing system has been changed (e.g. repeater addition to the BEAMSYNC system). The new value of the calibration is send to the hardware as soon as the Hardware Setup Menu is closed (no effect on closing the pattern menu). The following alignments must be made.

I. VXI-UCD module
   A. delay of PPG trigger -> avoid aligning clock with trigger.
   B. delay of pulse that triggers PPG -> first turn alignment
   C. shift of PPG pattern -> align pattern index with bunch index
II. V440 module
   A. Trigger delay -> long cable correction (clock interval stepsize)

The shift of 53Mhz clock on ECL1 is always set to zero as recommended for best phase response of the VXI-UCD card. The delay of the PPG trigger has the same effect on the alignment of the clock and trigger.

Procedure I.A

Missalignment could result in samples being taken one clock cycle earlier or later as determined by jitter on the clock or trigger pattern. The clock edge and the trigger as synchronous and therefore can be aligned away from each other such that the jitter can not cause a clock edge to pass a trigger edge or vice versa. This procedure should only have to be done once per hardware setup as the factors involved are the timing path delays in VXI-UCD card and the V440 card.

The procedure for alignment in the lab is as follows. set the system up for normal operation with the following modifications:

1) Connect the simulated BSYNC pulse to the digitizer CHAN 0 route and EXT0 of the VXI-UCD card.
2) Load a pattern with only one up edge.
3) Use multihit sampling of a full turn so that each bucket is sampled.
4) modify the trigger delay vernier until the BSYNC pulse changes position.

3.1 Signal

The following adjustments can be made to properly sample and process the beam position signal.

I. V440 module
   A. Channel offset -> correct for signal offsets
II. Analysis
   A. Signal scaling -> convert from Volts to millimeters.

4. Pulse to bunch assignment

Each pulse will trigger a sampling and consecutive analysis of the beamloss signal. The results of this analysis are stored into up to 36 locations (36 on 36 operation). The pulse to bunch assignment can be done automatically or manually. The automatic assignment takes the first bucket location of the pulse (as defined in the pulse pattern menu) and multiply this location with 36/1113. The resulting integer is the bunch assignment. This results in an array of bunch indices with the index being the pulse id. However, the first pulse sampled is not necessarily the first pulse defined. The first pulse sampled is the first pulse after the position pulse. The position pulse can be anywhere (see Introduction) and thus the pulse to bunch id array is rotated so that the first bunch id is that of the first pulse sampled (FW Acq BunchID). For each pattern such an array is created and all these arrays are combined into a 2 dimensional array with pattern as its upper (outer) index and bunch ID as its lower (inner) index. This information is passed to the settings by the TFW ReadGlobals. The array size is 40 by 40 (FW Menu Flyspec BunchPat)

NOTE: **The delay of the pattern as defined in the flyspecs is not taken into account.**

Multi-hit versus single hit

The V440 has two modes of operation, Multi Hit and Single Shot. In Multi-Hit mode the digitizer will take a number of samples defined by the Post Trigger register for each trigger it receives. In Single Shot mode it continuously takes samples after being armed and after the trigger take a number of samples defined by the Post Trigger register before coming to completion. Thus the settings of the operation mode, the Post Trigger register and the triggers, defined by the pulse pattern in the VUCD, determine how data is taken. The digitizer will always fill up all 64 kilosamples with new data unless interrupted. In Multi-hit mode (TBT) the digitizer will take Hits/trigger samples after the trigger, thus the number of sample to retrieve is Hits/trigger. In Single-shot mode (TBT) all 64k memory will be filled.